Applications of Solvent Extraction : A Summary

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Abstract

This paper summaries the processes involved in solvent extraction plus its various applications in the organic and inorganic chemical industries.

Solvent Extraction

Solvent extraction is a separation technique which should strictly be called liquid-liquid extraction as the term solvent extraction could be confused with the recovery of components from solids by treatment with an organic solvent. It involves contacting the original mixture (feed) which contains one or more of the desired components (solutes) with a second liquid (solvent) which is immiscible or partially immiscible with the original solution. The resultant mixture is then split into two separate phases of 'extract' containing the required solute and 'raffinate' which is the depleted feed with a certain amount of solute. The solvent which is made up of a mixture of extractant and diluent must be chosen such that the desired solute is transferred or extracted with the solvent. Its selection usually involves a compromise between different conflicting properties involved. (Hughes, 1989).

Solvent extraction is divided into two broad categories based on molecular interaction between the solute and the solvent;

(1) physical interaction which possibly involves polarity difference or hydrogen bonding.
(2) chemical compound formation.

The nature of the interaction dictates to an extent the type of equipment which may be used and also the methods of solvent recovery. In general, extraction of an organic material usually involves physical interaction whereas inorganic and metal species involves chemical interaction.

The extraction process involves

(1) contacting the solvent with the feed with an approach towards equilibrium.
(2) removal of impurities in the extract (scrubbing) by contacting the extract with another liquid (scrub feed) usually the original feed which is immiscible with the extract so that the desired solute retained in the extract while the impurities go into the scrub feed.
(3) recovery of solvent and solute from the extract phase (stripping/backwashing) which involves contacting the extract with a second immiscible liquid phase under conditions in which the solute passes to the second phase.

In a physical interaction extraction, the solute recovery from the extract is by physical means (usually distillation) whereas in a chemical interaction, the solute recovery requires reversal of the chemical interaction achieved by some form of chemical conditioning (for example, contacting with an aqueous phase of different pH).

Solvent washing is sometimes required if the solvent is subjected to degradation in use or if some impurity is extracted which is not removed in the stripping operation. Figure 1 shows the simplified process involved. In large scale operation, the operations are continuous and multistage.

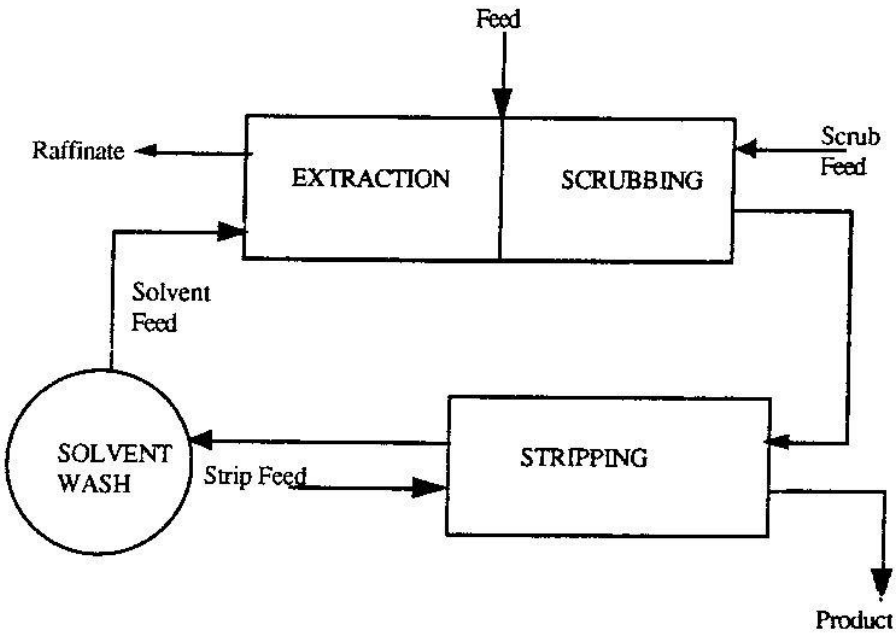

Figure 1 : Simplified Overall Extraction Process.(Hughes,1989)

Application of Solvent Extraction

Solvent extraction is chosen when

(a) it is the only method available since separation cannot be achieved by distillation, evaporation and crystallization or

(b) it is the most economical process. Due to this reason, solvent extraction has found applications in the separation of

(1) solutions of close boiling and azeotrope-forming components
(2) solutions of components having low relative volatility
(3) dissolved solute when evaporation may be impractical
(4) heat-sensitive components such as antibiotics and penicillin

(5) components of differing chemical type whose boiling points may overlap such as petroleum.

(Hughes,1989; Laddha and Degaleesan,1976)

The application of solvent extraction is broadly classified into organic and inorganic chemical industries with applications in the petroleum industries, coal tar industries, refining of vegetable oils and animal fats, separation and purification of pharmaceutical and natural products, recovery of pollution chemicals, metallurgical industries and fertilizer industries. There is currently considerable research effort particularly in metallurgical extraction to increase the application still further. (Bailes et al.)

Tables 1 and 2 give the various applications of solvent extraction in the organic and inorganic chemical industries. (Laddha and Degaleesan,1976)

From the examples of its vast applications, solvent extraction offers great potential as a separation and purification method in chemical engineering operations.

Table 1 : Important Application of Liquid-liquid Extraction in Organic Chemical Industry

Feed	Solvent	Solute	Remarks
PETROLEUM INDUSTRY			
Petroleum fractions in the boiling range from kerosene to lubricating oil	Liquid sulphur dioxide	Aromatic and sulphu-containing compounds	Edeleanu process. First installation in 1911
Petroleum stocks of wide boiling range	A mixture of diethylene glycol and water	High purity aromatics-benzene toluene and xylenes	Udex Process - recovery of aromatics 91 - 99% and purity 96 - 98
Diesel oil, heating oil & lubricating oil fraction	Furfural	Sulphur-containing and cyclic compounds	Treatment improves cetane number and qualities
Wax containing heavy crude residuums	Propane	Wax and Asphaltic materials	Asphaltic and resinous materials are insoluble in propane
Crude distillate	Propane and creasylic acid	Paraffins and napthalene	Duo-sol process
Low viscosity spindle oil and high viscosity machine oil	Dichloroethane and methylene chloride	Paraffin wax	Di-me solvent process
Gasoline and kerosene fractions	Sulfolane	Aromatic hydrocarbons	High purity aromatic hydrocarbons obtained
Catalytic reformates, straight run gasoline or kerosene	Dimethyl sulfoxide (DMSO)	Aromatic hydrocarbons	
COAL TAR INDUSTRY			
Coke-oven oil	Diethylene glycol-water	Aromatics	Udex process
Crude tar distillate	Aqueous methanol and hexane	Tar acids	Fractional extraction
Commercial tar acid fraction	Aqueous sodium hydroxide and toluene	2-4 and 2-5 xylenol	Dissociation extraction
Gas liquor	Benzene	Phenols	
OILS AND FATS			
Vegetable oil and animal fats	Propane	Unsaturated glycerides and vitamins	Solexol process
Vegetable oils	Furfural	Unsaturated glycerides	For production of drying oil

(cont'd table 1)

Feed	Solvent	Solute	Remarks
PHARMACEUTICAL			
Fermentation broth	Butyl or amyl acetate	Penicillin	Multiple rapid extraction
Soyabean meal fermented beer	Butanol	Bacitracin	
MISCELLANEOUS			
Dilute solution of acetic acid	Ethyl acetate	Acetic Acid	
Pulpmill black liquor	Methy ethyl ketone	Acetic acid and formic acid	
Catalytic cracking petroleum plant effluent water	Light catalytic oil	Phenol	Phenex process

Table 2 : Important Application of Liquid-liquid Extraction in Inorganic Industry

Feed	Solvent	Solute	Remarks
METALLURGICAL INDUSTRY			
Low quality sulphuric acid ore-leach liquor	Secondary and tertiary amine	Uranium salt	Anex process
Ore-leach liquor	Di-2-ethyl hexyl phosphoric acid and tri-butyl phosphoric acid in kerosene	Uranium salt	Dapex process
Uranium concentrate solution in nitric acid	20% Tributyl phosphate in kerosene	Uranium nitrate	For final purification
Monazite leach solution	TBP in xylene or Di (tridecy) amine	Thorium nitrate	
Zirconium-hafnium solution	Hexane and tributyl phosphate or hexone and ammonium thiocyanate	Hafnium	Produces reactor grade zirconium
Mixed fluorides of niobium and tantalum	Hexone or TBP	Tantalum	Both tantalum and niobium are extracted by TBP
Uranium mill slime tailings	Di-2-ethyl hexyl phosphoric acid and TBP in kerosene	Vanadium	
Copper ore-leach solution	α-Bromolauric acid	Copper	
MISCELLANEOUS			
Phosphoric acid solution from phosphate rock digestion	C_4-C_5 alcohols	Phosphoric	IMI process
Bromide salt in brine	Tetrabromoethane	Bromine	
Hydrogen peroxide solution in anthra-quinone	Deionized water	Hydrogen peroxide	Autoxdation process

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